Title: COVID-19 Virtual Disease health System Outbreak model for Singapore (CoViD-SOS)

Abstract

As the COVID-19 outbreak unfolds it will lead to health system-wide consequences. These can be direct consequences experienced by COVID-19 patients; and indirect ones faced by non-COVID-19 patients due to decisions like cancelling non-emergency surgeries.

Therefore, our overall aim is to minimize effects of the COVID-19 disease outbreak on Singapore health systems' outcomes through understanding system-wide effects using existing data and computer simulation techniques that will lead to informed policy decisions.

Building upon local data, we will: 1) Build computer simulation models to: a) evaluate impact of policies on health systems estimating overall deaths and admission, complications and length of stay in healthcare facilities; b) understand infectious disease effects on various high risk population sub-groups. 2) Assess actual health services utilization due to COVID-19 and non-COVID-19 conditions through analyzing electronic records. Detailed interviews of patients and other stakeholders will enrich our understanding. Costs of care will also be assessed capitalizing on routine data sources. 3) Evaluate policy experiments, through another series of computer simulations of potential scenarios a)COVID-19 remains under control; b)difficult to control with local clusters c)full-blown local epidemic.

This proposal will use sophisticated simulation modelling and analyses to inform current and future policy decisions locally and even globally.

Introduction

As the COVID-19 outbreak unfolds it is becoming evident that COVID-19 (and likely similar future infectious disease outbreaks) impact not only the infected/affected individuals, but also individuals with non-COVID-19 conditions through highly dependent health systems. We hypothesize that COVID-19 has already affected and will continue to impact the entire health ecosystem via direct and indirect consequences. These consequences will be particularly acute on vulnerable populations and need to be mitigated by appropriate policy responses. We anticipate direct and indirect consequences of the outbreak as follows:

1. Direct consequences refer to impact of COVID-19 on health outcomes such as mortality, morbidity, resource utilization and costs. With a relatively small number of cases, this is likely to be a relatively small component of the overall problem.
2. Indirect consequences are the health and economic effects of policy response on non-COVID-19 patients and might be considered in two categories:
a. The downstream effects of changing the typical production process within hospitals. In particular, orientating the acute care sector on a 'war footing' for COVID-19. Items such as infection prevention practices, screening for disease, re-designating existing infrastructure for large numbers of cases, contact tracing and use of personal protective equipment are relevant.
b. The opportunity costs measured in healthcare provision and monetary losses such as cancelling planned medical and surgical admissions, routine outpatient care and the normal day-to-day work of evaluating patients for symptomatic management and diagnosis. The likelihood is that waiting time will be extended and delays in providing healthcare will worsen outcomes consequently increasing costs in the medium to long term.

Thus, the overall aim of our proposal is to improve the health systems' outcomes adversely impacted due to the COVID-19 disease outbreak in Singapore by advising policy and practice through whole-system modeling (incorporating both COVID-19 and non-COVID-19 needs and services), using existing data and novel modelling methods. We aim to identify appropriate strategies to mitigate these untoward effects through measured policy responses considering the overall population, while prioritizing the medically vulnerable.

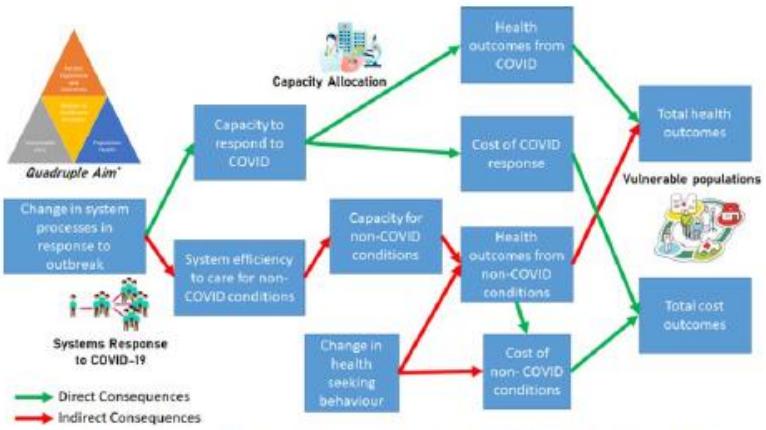

Figure 1: Direct and indirect consequences to COVID-19 (Adapted from Institute of Medicine's definition of the Quadruple Aims)

Taking advantage of substantial previous and ongoing work on modeling, survey research, as well as ongoing primary and secondary data resources, proposed work can be done in a reasonably short time.

How our research will contribute

Our proposal is a unique health services and systems dynamic approach to infectious disease modelling looking at the entire health system. The development of the COVID-SOS model together with the quantitative and qualitative analysis of existing data and stakeholders' opinions will enable effective evaluation of policies and scenarios focused on total health and cost outcomes. This will enable the health system to function and achieve the quadruple aims related to patient outcomes, sustainable care delivery, population health and the welfare of care providers in the current COVID-19 outbreak situation.

This study will build on prior disease modelling our team has been working on, in collaboration with Assoc Prof Alex Cook, (SPH NUS). A/Prof Cook's team have developed computer simulation models and traditional SEIR-style models to inform MOH's response to the outbreak. We intend to complement these efforts by adding a unique high-level, healthcare system-wide, systems-dynamic models that will address questions related to excess mortality and morbidity in our vulnerable groups in the population, using data readily available from Singhealth population-based cohorts and databases. In addition, we have done extensive prior work to segment our regional health system population, and identified segments that are especially vulnerable to health system shocks like COVID-19. In addition, we will add a health economics impact analysis, which is a strength we have at Duke-NUS.

The COVID-SOS model can be adapted in the future for other acute infectious disease outbreaks and can serve as a virtual simulation modelling platform that can be utilized to deal with external shocks to the healthcare system brought about by unexpected epidemics. Through the COVID-19 use case, generalizable insights, such as the effective use of multimethod modeling framework to model the relationships in planning parameters at the strategic to tactical levels, can result in insights that can unravel problems that have traditionally weakened healthcare systems in their ability to effectively deal infectious disease outbreaks at a national and global scale.

Preliminary Studies/Progress

A. COVID-19 Infection Model: Based on available local and international data, the PI and his team have developed a COVID-19 Infection Model for Singapore, which is a continuous time compartment model using the system modelling methodology of system dynamics [7]. The preliminary COVID-19 infection model has the ability to test "what if scenarios" for instance the impact of contact tracing and isolation of community spread of COVID-19.

B. Population segmentation into categories of health and social service's needs: Prof. David Matchar and A/Prof John Ansah have an ongoing research that aims to segment the population of Singapore into categories of health and social service's (HASS) needs using the Simple Segmentation Tool (SST) [8], [9]. This approach has been applied to THE SIGNS Study, a national survey of community-dwelling Singaporeans 60 years and older to estimate the transition rates across categories of segments. This work based on THE SIGNS is especially salient as the most recent wave of data collection occurred just prior to COVID-19.

C. Health Services Resource Allocation Model: Based on available clinical and operational data, the team has developed a detailed ED and Operating Theatre (OT) resource simulation and optimization models from previous projects [10]–[14]. The team has also successfully developed prediction models for short to medium term Bed Occupancy Rates (BORs) [15], [16]. The process knowledge and handover intricacies across the entire care chain within the hospital and handovers to the primary and community care setting will be available for the integration of all the modelling framework.

D. Stakeholder engagement: We have already been extensively engaging stakeholders at MOH, MOHT, Singhealth leadership and frontline staff with our preliminary models and received good feedback on their utility and helpfulness to address specific questions using our simulation models.

Methods/Approach

Tasks for SPECIFIC AIM 1: Build a Computer Simulation Model

Tasks for SPECIFIC AIM 2:

AIM 2A: Estimate changes in health services use attributable to COVID-19 and non-COVID-19 conditions among medically vulnerable individuals

AIM 2B: Examine responses of patients and key stakeholders

AIM 2C: Examine the health economic consequences

Tasks for SPECIFIC AIM 3: Three Scenarios. (i) Best-case scenario, (ii) Preparedness scenario, (iii) Worst-case scenario.